INDUSTRIAL MERCURIALISM
Report of an Investigation

OHIO DEPARTMENT OF HEALTH
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FOREWORD

The ultimate goal of the Ohio Department of Health is the prevention of occupational diseases by the control of those conditions in industry which affect the health of workers unfavorably.

The Industrial Hygiene Program of the Ohio Department of Health is assigned to the Adult Hygiene Division and this report is presented in the hope that it may be of value to physicians and others responsible for the protection of the health of industrial workers.

Acknowledgment of the painstaking effort in the conduct of this investigation and preparation of this report is made to the technical staff of the Adult Hygiene Division as follows:

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GENERAL INTRODUCTION

An investigation of conditions affecting the health of employes, reviewed in the following paragraphs, was undertaken by the Ohio Department of Health at the request of the management of a company engaged in the manufacture of an electrical apparatus containing copper amalgam and made by a secret process.

A communication from the company stated that employes were suffering from "sore mouths". The communication added that the employes believed they were suffering from mercury poisoning, while the company officials thought the sore mouths might be due to an epidemic of Vincent's Angina or trench mouth.

Besides gingivitis, preliminary examination of sixteen of the employes' group by a Health Department physician elicited the occurrence of many other cardinal symptoms of mercurialism, and this, in conjunction with the known presence of mercury in the processing operations, was considered justification for a tentative diagnosis of mercury poisoning. In order to exhaust every resource leading to the establishment of a definite diagnosis and a final solution of the problem, smears were made of the mucous membranes of the buccal cavities of all of this group. These smears were examined by the Ohio Health Department Laboratories in Columbus and found to be negative for the organisms of Vincent in each instance. Other organisms normally inhabiting the mouth were present in profusion and thus faulty technique could not have been responsible for failure to demonstrate pathogenic organisms responsible for the gingivitis. (105) Mouth smears of all employes made at later dates were reported negative except two which were reported as suspicious. This proportion of suspicious findings is not unusual in an examination of any 105 smears.

The results of the preliminary examination of the sixteen employes arbitrarily selected are sufficiently interesting to be summarized as follows: All, except one, complained of excessive flow of saliva and sore gums, mostly in the region of the molar teeth. Perceptible gingival lesions were not apparent in more than three or four instances. One lesion involving the tonsil was noted. Dysentery of recent occurrence was stated by five (two of bloody diarrhea). Constipation was stated by three. History of digestive disturbance was obtained in three instances. Fine tremors were noted in four instances. Skin eruptions having the appearance of itch or scabies were manifested by three or four. No psychic phenomena or erethism was observed or elicited by questioning.

Following the preliminary examination of this group of employes and the establishment of a diagnosis of mercurialism affecting more or less severely a considerable number of workers, plans were formulated for a detailed study which would solve the problems presented by such a situation and lead to adequate control of this dangerous exposure.

PROPERTIES AND USES OF MERCURY

This report is concerned only with mercury in its elementary state and combined with certain metals to form amalgams. Mercury is a silver-like liquid at ordinary temperatures which boils at 357.2°C. (675°F.) and freezes at -38.85°C. (-37.9°F.). At room temperature 25°C. (77°F.) the vapor pressure of mercury is 0.0018 mm. and the maximum theoretical concentration of mercury vapor at this temperature is approximately .021 mg. per liter of air. This increases rapidly with increase of temperature so that at 60°C. (140°F.), a temperature frequently associated with certain manufacturing processes, one could attain a concentration of 0.350 mg. of mercury vapor per liter of air.

When mercury is associated with certain metals such as copper, silver, and gold the resulting products are known as amalgams. In this form, the vapor pressure of mercury is lower than that of free metallic mercury at the same temperature. In fact, the vapor pressure of an amalgam is dependent on several factors including the nature of the metal or metals associated with the mercury, the amount of mercury present and the temperature of the amalgam. It should be emphasized, however, that all amalgams have an appreciable vapor pressure and at elevated temperatures they may become a significant source of mercury vapor in the air.

Other properties of mercury such as electrical characteristics, chemical properties and compounds are omitted here since they have no significant relation to the hygienic aspects of this study.

Mercury is used extensively in a variety of ways. Some of the uses of metallic mercury and its compounds are included as follows: Manufacture of mercury salts, instruments and thermometers, medicine, mercury vapor lamps, amalgams, extraction of gold and silver from their ores, catalysts, production of fulminate, electric rectifiers, electrical equipment, pharmacy, electrolytic chemical processes, felt manufacture, mercury boilers, cosmetics and petroleum refining.

HISTORY OF MERCURY POISONING

Many of the uses of mercury indicated in this paper are of recent origin. However, mercury has been known and used for many years, and its poisonous properties have long been recognized. It was used for industrial purposes in Egypt in 1600 B.C., in Greece 400 B.C., in Rome 100 B.C., and in the Roman Empire 100 A.D. In 430 B.C., Hippocrates wrote a short description of mercury poisoning in workmen. Pliny, the Younger, in writing of the disease of slaves mentioned mercurialism along with plumbism and the consumption of potters and grinders.

Mercury was used for medicinal purposes in India 500 B.C., in Persia 200 A.D., in Arabia 650 A.D., and in North Africa and Spain 8 A.D. About 850 A.D., mercury was used medicinally as an ointment, and in 1170 A.D., it was used in the treatment of chronic skin diseases. In 1495, there was an increased demand for mercury following its use in the treatment for syphilis (Paracelsus).

Early in the sixteenth century, Andrea Mattily wrote a description of chronic mercurialism in the workers of the Idria mercury deposits

of Austria. In 1690, Ramazzini discussed industrial mercury poisoning and in 1761 Giovanni Scopali wrote a description of mercurial tremor in Idria workers.

Quick silver has been mined in Spain since Roman times and Spain today ranks first in the production of mercury. For many centuries work in the Spanish mines was carried on by slaves and convicts. Later, when free labor was introduced, the hours of work were limited, due to the large amount of incapacitating illness among the men. A practice was developed in which eight days of four and one-half hours each, thirty-six hours in all, constituted a month's work.

Italy ranks second in the production of mercury. Here, a system of alternation of work was developed in 1897 by which the men were shifted periodically after one month of furnace work to two months of outside work and back again. The result was that the number of cases of mercurialism fell from 122 in 1896 to 5 in 1908. The United States now holds third place in the World's production of quick silver, the greater part of the metal coming from California and Texas. The quick silver mines of California are not deep, a few running down about 500 feet below the outcrops. Ninety-five per cent of the output is from cinnabar, HgS, which carries little if any mercurial hazard in mining. Quick silver is also found in droplets where the men say "the silver runs free". These deposits were worked during the World War because of the great demand for quick silver to make mercury fulminate for percussion caps which is its largest use. The mouths and lips of workers after two weeks became swollen and inflamed and their teeth so sore that solid food could not be chewed. One doctor reported that the men not only became poisoned themselves, but they carried home so much mercury in their clothes that their wives became salivated while washing their clothes.

The metallurgy of mercury is simple, but considerable potential exposure exists in the roasting process. Volatilized mercury is encountered in furnace work, in cleaning out the condensers, and in working at the steam tables.

TOXICOLOGY OF MERCURY

Toxicologically, mercury is classed as an irritant poison. It may be absorbed as vapor or in the form of soluble compounds of mercury. In the presence of certain substances, the solubility of mercury compounds is increased. The greater the degree of solubility the greater will be the rate of absorption.

Mercury forms albuminates in reaction with cellular protoplasm and probably circulates in the blood stream as mercury oxychloralbuminate. Mercury is stored by the kidneys, liver, spleen and bones. The rate of excretion of mercury is influenced by exercise, intake of calcium and hydrogen ion concentration of the blood. Characteristically, the manifestations of poisoning by mercury are noted at the point of excretion. Mercury is excreted by the kidneys, bowels, skin, saliva, milk, and bile.

The nephritis so often encountered is believed to be directly relatable to excretion by the kidney, salivation to excretion by way of the salivary glands, and colitis to excretion by way of the large bowel. The central nervous system manifestations of mercurialism are due to a diffuse encephalopathy, in the opinion of some authorities, with predominance of symptoms referable to the cerebral centers most affected.

Youth, female sex, alcoholism, and infection appear to be etiological factors, increasing susceptibility or lowering resistance to the poison.

SYMPTOMATOLOGY OF MERCURIALISM

The symptomatology of mercury poisoning is voluminous and may be arbitrarily classified as due to acute poisoning from relatively large doses of the poison within a short period of time and chronic poisoning due to smaller doses continued over a longer interval.

For practical industrial consideration, entrance into the body may be limited almost entirely to inhalations of vapor and less frequently to inhalations of finely divided dust. Ingestion, inunction, and subcutaneous injection, although recognized as clinical sources of entrance, are of little significance in industry.

The symptoms of acute mercury poisoning vary, of course, with the amount and rate of absorption of the poison and the mode of entrance into the system. Stomatitis, salivation, and discoloration of buccal mucous membranes, polyuria, albuminuria, anuria, diarrhea, and abdominal pain are characteristic of acute poisoning.

Chronic mercury poisoning is characterized by nervous disorders as evidenced by psychic disturbances or erethism and tremors, vasomotor disturbances, headache, digestive disturbances, insomnia, loss of weight, pallor, weakness, polyuria, mercury line on gums and, among females, disturbances of menstruation and climacteric. If the poisoning is continued long enough, gingivitis and loosening of the teeth are also encountered in the chronic form as well as in the acute form.

Differentiation between acute and chronic mercury poisoning is based on the amount and rate of absorption rather than upon any inherent difference in the symptomatology of the two forms of intoxication. Symptoms may range from the slightest to the most severe and oftentimes it may be impossible to draw a sharp line of demarcation between the two forms.

In the investigation herein described, the complex of symptoms encountered were of such a degree of severity as to fall neither into the classification of acute nor chronic poisoning. The predominant impression inclined rather more to the acute than to the chronic, so a compromise "sub-acute" classification was adopted for the diagnostic designation of this series of cases.

ENGINEERING AND CHEMICAL STUDIES

Mercury was used in the form of a copper amalgam in the processes studied. The amalgam was prepared by mixing copper powder and free mercury in the presence of dilute sulfuric acid. The amalgam was then dried in a steam-heated vacuum dryer. Mercury was vaporized during the drying period since about 10 pounds of mercury was collected in the attached condenser every few months. The workmen were exposed to the mercury vapor from the dryer only during loading and unloading periods. The dry amalgam, graphite, and various bonding agents were thoroughly mixed under pressure at a temperature of 180°F. Again mercury vapor escaped into the working room during the period of unloading the mixer.

The amalgam-graphite mixture was pressed into cakes while hot. The final product was formed from the pressed cakes by sawing, grinding, drilling, etc., and then baked in ovens at a temperature of 500°F. In order to keep the temperature constant, the ovens were not exhausted.

Mercury vapor determinations were made, using the Nordlander apparatus and the following results were obtained:

Series I

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of amalgam maker	0.0
2	Vicinity of mixer (unloading)	20.
3	Vicinity of grinder and south end of building	12.
4	Vicinity of press	12.
5	Vicinity of storage room	45.
6	Vicinity of ovens	85.
7	Vicinity of grinders (10 ft. from ovens)	60.
8	Vicinity of vacuum dryer (open)	17.

It was evident from the above data that the ovens were the largest contributing factor in creating harmful mercury vapor concentrations. It was recommended that the ovens be removed from the working room to a small building adjacent to this department and that all of the grinding wheels, saws, etc., be properly exhausted.

Three weeks later, the above recommendations having been carried out in the interim, another series of samples were taken with the Nordlander apparatus and the following results obtained:

Series II

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of press	0.0
2	Vicinity of press	0.0
3	Vicinity of press	0.0
4	Vicinity of mixer (loading)	0.0
5	Vicinity of ovens (not baking amalgam product)	0.0
6	Vicinity of carborundum sawyer	0.0
7	Vicinity of ovens (baking amalgam product)	23.0
8	Vicinity of semi-automatic grinder	0.0
9	Vicinity of mixer (unloading)	3.8

The only mercury vapor exposures found on this visit were in the vicinity of the ovens and near the mixer during unloading. The ovens, however, were removed to another building and the attendant was exposed to the mercury concentrations found there only a few minutes a day. No workmen were employed in the building to which the ovens had been moved.

Four weeks later another series of mercury vapor determinations were made with the following results:

Series III A (Mercury Vapor With Nordlander Apparatus)

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of presses	trace
2	Vicinity of tumbler (mixing graphite and bond)	0.0
3	Second floor	0.0

Due to the dustiness of certain operations, it was thought advisable to determine the amount of mercury in the air present as amalgam dust. Since the Nordlander apparatus was sensitive only to mercury vapor, the mercury dust samples were collected with the Greenburg-Smith impinger. Seven samples taken during this visit gave the following results:

Series III B (Amalgam Dust With Impinger Equipment)

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of press	trace
2	Vicinity of press	0.12
3	Vicinity of tumbler	1.08
4	Four feet from tumblers	trace
5	Vicinity of mixer (charging)	270.
6	Five feet from mixer (charging)	4.0
7	Vicinity of band saw operator	0.13

The mercury dust concentrations were found to be very high at the point of emission and were much lower a few feet away. The high density and large particle size of the amalgam dust were undoubtedly the cause for this decrease.

Three additional series of mercury vapor and amalgam dust determinations were made, the final determination being carried out approximately eight months after the first investigation. The following results were obtained:

Series IV A (Mercury Vapor With Nordlander Apparatus)

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of presses	0.0
2	Vicinity of mixer	0.0
3	Vicinity of tumbler	0.0
4	Vicinity of grinder	0.0
5	Vicinity of grinder	0.0
6	Vicinity of vacuum dryer	0.0
7	General atmosphere	0.0
8	General atmosphere	0.0

Series IV B (Amalgam Dust With Impinger Equipment)

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of drilling operation (first floor)	0.0
2	Vicinity of crimping operation (first floor)	0.0
3	Vicinity of automatic soldering (second floor)	0.0
4	Vicinity of tamping machinery (second floor)	0.0
5	Vicinity of hand soldering (second floor)	0.0
6	Center of room (second floor)	0.0
7	Vicinity of hand soldering (second floor)	0.0
8	Vicinity of crimping operation (second floor)	0.0
9	Vicinity of breaking operation (first floor)	0.0
10	Vicinity of crimping operation (first floor)	0.0
11	Vicinity of mixer (charging)	234.
12	Vicinity of mixer (four feet away while charging)	3.6
13	Vicinity of grinder operator	0.0
14	Six feet from grinder	1.0
15	Vicinity of tumbler (loading)	2.7
16	Five feet from tumbler (loading)	0.27
17	Vicinity of tumbler (not loading)	0.0
18	Five feet from tumbler (not loading)	0.18
19	Vicinity of tumbler (unloading)	0.54
20	Five feet from tumbler (unloading)	0.0
21	Vicinity of mixer (unloading)	28.0
22	Three feet from mixer (unloading)	0.51
23	Vicinity of mixer (after unloading)	0.06
24	Three feet from mixer (after unloading)	0.54
25	Vicinity of semi-automatic grinder	0.0
26	Vicinity of ovens	0.15
27	Vicinity of mixer (in operation)	0.21
28	Vicinity of carborundum saw	0.0

Series V A (Mercury Vapor With Nordlander Apparatus)

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of grinders	0.0
2	Middle of factory	0.0
3	Vicinity of saw bench	0.0
4	General atmosphere, north side	0.0
5	Middle of room, second floor	0.0
6	General atmosphere, north side	0.0
7	Top of press	2.5
8	Eight feet from press	0.0
9	Same as No. 7 except hot plates have been taken away	1.0

Series V B (Amalgam Dust With Impinger Equipment)

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of emery wheels	0.07
2	Vicinity of emery wheels	trace
3	Vicinity of presses	0.0
4	Vicinity of presses	0.0
5	Vicinity of band saw	0.0
6	Vicinity of band saw	0.0
7	Vicinity of presses	0.0
8	Vicinity of presses	0.0
9	General atmosphere (second floor)	0.0
10	General atmosphere (second floor)	0.0
11	Vicinity of tamping operation (second floor)	0.0
12	Vicinity of tamping operation (second floor)	0.0
13	Vicinity of presses	0.0
14	Vicinity of presses	0.0

Series VI A (Mercury Vapor With Nordlander Apparatus)

Sample No.	Description	MgHg/10 cu.m.
1	New oven building	0.0
2	New oven building	0.0
3	New oven building	0.0
4	New oven building	0.0
5	Vicinity of soldering operation (second floor)	0.0

Series VI B (Amalgam Dust With Impinger Equipment)

Sample No.	Description	MgHg/10 cu.m.
1	Vicinity of vacuum dryer (emptying)	trace
2	Vicinity of vacuum dryer	0.36
3	Vicinity of lead soldering machine	0.0
4	Vicinity of solder heating	0.0
5	Breathing level of solderers	0.0
6	Vicinity of solder heating	0.0
7	General atmosphere (front of building)	0.0
8	General atmosphere (front of building)	0.0
9	General atmosphere (rear of building)	0.0
10	General atmosphere (rear of building)	0.0

MEDICAL STUDY

Procedure of medical studies followed in general that of the U.S. Public Health Service study in the hatter's fur cutting industry. The medical forms (history, physical examination, and laboratory) were somewhat similar to those used in the classic "hatter's fur cutting study". Both history taking and physical examination were done by the same physician. Mimeographed forms were utilized to record essential data and to systematize the conduct of examinations. Space was provided for name, sex, age, race, marital status, occupational history, past medical history, habits, questions for females, present history, subjective symptoms, physical findings, and laboratory data. Particular attention was given on history and physical examination to signs and symptoms which might be caused by or result from deleterious exposure to mercury.

Age Groups and Length of Employment

Thirty-four of the females (89.5 per cent) were in the age groups 20-29 years, while 46 males (63.7 per cent) were in this same age group. Sixteen males (23.9 per cent) were in age group 30-39 years. The others were in older or younger age groups.

Twenty-one females (55.3 per cent) had been employed over one year; 3 females (7.9 per cent) employed less than 1 year but more than 6 months, while 14 females (36.8 per cent) were employed less than 6 months. Ten of the latter 14 females (26.3 per cent) were employed less than 4 months, when quantity production began. Fifty-three males (79.1 per cent) had been employed over 1 year; 14 males (20.9 per cent) employed less than 6 months; 11 of these latter 14 (16.4 per cent) employed less than 4 months.

Past History

Nothing of unusual significance was found in analysis of the past history.

Present and Immediate Past History

In the present and immediate past history, numerous symptoms were elicited, more frequently among the female workers. Mention will be made of the most frequent complaints.

Gingivitis was a frequent complaint at time of examination or a recent occurrence according to the history obtained in 19 females (50.7 per cent) and 22 males (30.5 per cent). On examination, gingivitis of some degree was found in 9 females (23.7 per cent) and 5 males (7.5 per cent). This gingivitis usually took the form of injected irregular areas along base of gums, observed best on the buccal surface. The only two female employes compelled to lay off work because of symptoms showed definite, dusky, coppery colored, deeply injected areas along entire base of gums. A few exhibited small light anemic appearing areas which they stated were sore. A few complained of sensitivity of teeth when eating.

Loss of weight was stated by 8 females (21 per cent) and 18 males (26.8 per cent).

Ptyalism was believed to be present by 7 females (18.4 per cent) and 4 males (5.9 per cent). On examination, it was definitely observed to a slight extent only on 3 females (7.9 per cent) and 2 males (2.8 per cent).

Symptoms Referable to Gastro-Intestinal Tract

Symptoms referable to gastro-intestinal tract were complained of by many of the employes. They will be mentioned briefly in order of frequency.

Abdominal cramps of some degree were first in frequency and were complained of by 19 males (28.3 per cent) and 10 females (26.3 per cent). Second in frequency was constipation - 13 males (19.4 per cent) and 13 females (34.2 per cent) according to history. Several gave a history of alternate constipation and diarrhea.

Nausea, third in frequency, was complained of by 11 males (16.4 per cent) and 8 females (21 per cent). None had actual vomiting. Diarrhea, fourth in frequency, had been noted by 10 males (14,9 per cent) and 7 females (18.4 per cent). Diarrhea with slight amount of blood had been noted by 7 males (10.4 per cent) and 2 females (5.2 per cent). Sixth was abdominal swelling, usually of slight degree, 5 males (7.4 per cent) and 5 females (13.1 per cent) had noticed it. Loss of appetite, seventh in frequency, was admitted by only 2 males (2.9 per cent) and 6 females (15.7 per cent).

Symptoms of Psychic Irritability

Symptoms of psychic irritability were frequent; a greater percentage of complaints being elicited among the female group. These are mentioned in order of frequency. Restlessness was the most common complaint - 15 females (39.4 per cent) and 11 males (16.4 per cent). Irri-

tability, second in frequency, was believed to be more noticeable by 12 females (31.5 per cent) and 11 males (16.4 per cent). Third, 13 females (34.2 per cent) and 8 males (11.9 per cent) mentioned excitability as a symptom. Fourth, 14 females (36.8 per cent) and 7 males (10.4 per cent) stated they were somewhat discouraged at times.

A small number of workers (14 females - 36.8 per cent), and 7 males - 10.4 per cent) complained of bad dreams occasionally. Some complained of buzzing in the ears on occasion. A few other symptoms were elicited.

Physical Examinations

The group of 105 employes examined would be considered at least average in general appearance and intelligence. The chief physical findings and those of chief interest are of the nervous system.

Fine intention tremor of fingers of a slight or moderate degree was noted in 32 females (84.2 per cent) and 44 males (65.7 per cent). Twenty-three females (60.5 per cent) and 46 males (68.7 per cent) were recorded as showing a fine tremor of tongue. Two females showed a tremor of lips and one of these a tremor of face muscles.

Patellar reflex was noted increased in 19 females (50 per cent) and in 33 males (49.3 per cent). Increased bicep reflex was noted in 15 females (39.5 per cent) and 29 males (43.3 per cent).

Simple injection of mucous membrane of nose was noted in 12 females (31.6 per cent) and 22 males (32.8 per cent). This may in part be due to inhalation of graphite dust, etc., in the air incident to grinding, drilling and other operations.

Gingivitis as previously mentioned and described was noted in 9 females (23.7 per cent) and 5 males (7.5 per cent).

Many employes had considerable dental repair, a few, false dentures. The company had previously insisted on dental examination and repair if indicated in an effort to secure good mouth conditions among employes. The teeth, in general, were found in good condition. Pyorrhea was practically absent, being noted to a slight extent in about 6 people. Slight enlargement of the thyroid was noted in 1 female and 8 males. Overactivity of the gland was not considered as evident in any case, nor as a cause of tremor.

Blood pressure readings taken with standard mercury sphygmomanometer generally fell within normal limits - 6 males (9 per cent) gave a reading of 130; while 6 males (9 per cent) and 4 females (10.5 per cent) gave a reading below 110.

A few cases only of dermatitis were noted; not apparently associated with mercury poisoning. One case of psoriasis and two cases of scabies were found. A diagnosis of pulmonary tuberculosis was made on one female. Her physician subsequently confirmed this diagnosis by chest roentgenograms and physical examination.

Laboratory Study

Blood counts and clinical urine examinations were not particularly noteworthy. A slight increase in lymphocytes was noted in 20 males (29.9 per cent), and 11 females (28.7 per cent) had a relative lymphocytosis of over 40 per cent. Basophilic aggregation counts made according to the technique usually employed by the Ohio Department of Health were not noteworthy, being below 1 per cent in most instances.

Albumin was found in urine of 8 females (21.1 per cent) and 9 males (13.4 per cent). The tests for albumin were made by the sulphosalicylic acid method.

URINARY EXCRETION OF MERCURY IN EXPOSED WORKERS

It has been indicated in the engineering study that two types of mercury exposures prevailed in this study. First, the exposure to mercury vapor originating from the heating of copper amalgam which was promptly removed; and second, exposure to copper amalgam dust which continued to prevail to some extent after the vapor exposure had been eliminated. It is apparent that the knowledge of urinary excretion of mercury of exposed workers would be of material aid to evaluate the extent of each type of exposure. Since it was impractical to secure representative urinary specimens for analysis of mercury from all exposed workers, a group of twenty-three employes, all working on the same shift and representing all the operations in the various parts of the work rooms, were chosen.

The collection of the samples were carried out as follows: Sample bottles of one liter capacity previously cleaned were distributed to the employes chosen for the study. They were instructed to exercise every possible precaution to avoid the contamination of the sample with mercury and to return the collected urine to a designated room in the factory twice a day. The amount of each sample was recorded and one-fourth was saved for analysis. The remainder was discarded. This procedure was continued for four days and the combined samples representing one-fourth of all urine excreted over a period of four days were returned to the Laboratory for analysis. It is apparent that the final sample contained one-fourth of the total output of urine for the four-day period, and, in reality, contained one-fourth of each voided specimen for the entire period of collection. The procedure used in the analysis of these samples is described as follows: Two hundred and fifty milliliters of the sample returned to the Laboratory was oxidized with potassium permanganate and sulphuric acid. Two milligrams of copper were added and the mercury precipitated with hydrogen sulfide. The combined sulphides were suspended in water and treated with chlorine gas. The excess chlorine was removed and the mercury was determined by titration with standard dithizone solution in chloroform. Blank and control samples were carried through with each series of samples.

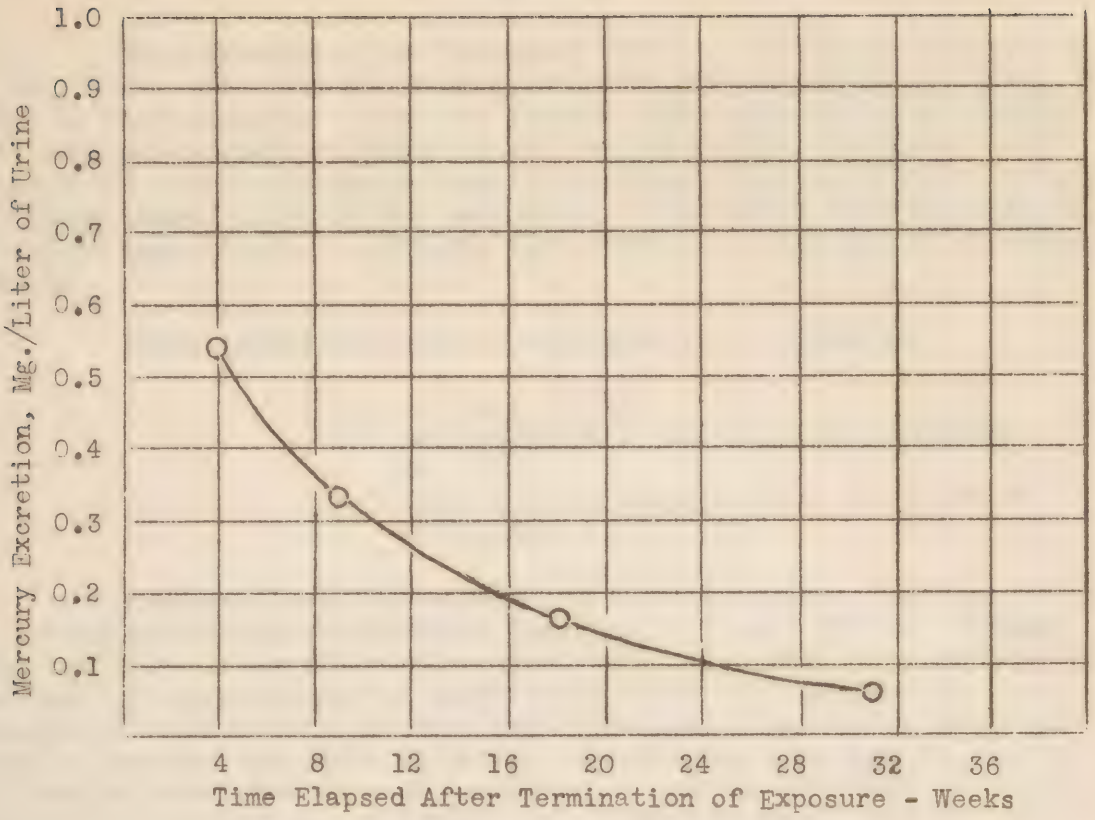
Four series of determinations on the same group of employes were made at various intervals. The first series was started on January 29th, the second on March 6th, the third on May 9th, and the fourth on August 8th, 1939. The January and March series represented four-day specimens,

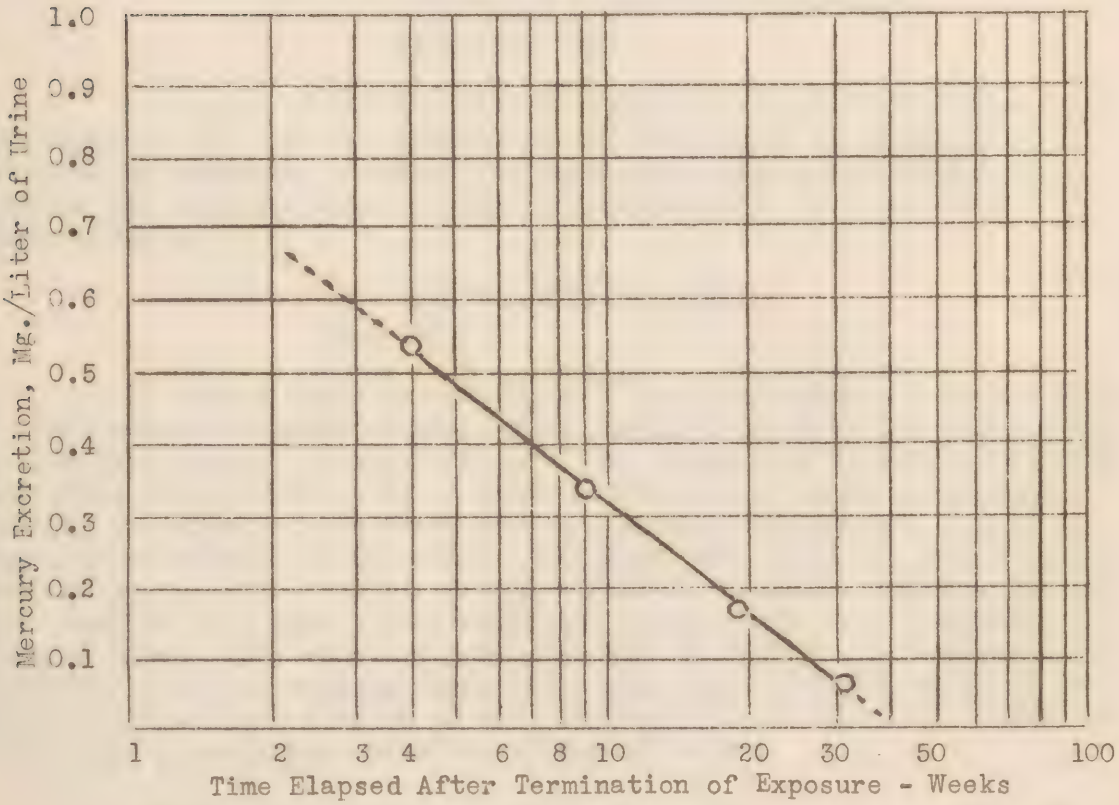
the May and August series were only three-day specimens. The results of the analyses for each individual are indicated in the following table and are listed in order of the decreasing concentration of mercury in milligrams per liter of urine as found in the first series. It will be noted that the table indicates the mercury findings in terms of milligrams per liter of urine. They could also be expressed in terms of milligrams of mercury excreted per day. Although cooperation on the part of the employes was generally very good, in certain cases it was suspected that the entire output of urine was not returned in the sample bottle. This would seriously affect the results of the daily output of mercury, but would not have such a serious bearing on the average concentration of mercury per liter over a four-day period. The following table lists the concentrations of mercury found in the urine for each individual studied in the four series of determinations.

Summary of Individual Urinary Mercury Excretions

	Weeks Elapsed After Termination of Mercury Vapor Exposure			
	4	9	18	31
Employee	Milligrams of Mercury per Liter of Urine			
A	1.11*	--	--	.05*
B	.84	.35	.28	.12
C	.79	.66	.28	.12
D	.78	.42	.18	.15
E	.77	.51	.45	.15
F	.72	.42	.15	.12
G	.61	.35	.15	.05
H	.60	.37	.07	.04
I	.59	.26	.60*	.05
J	.58	.34	.17	.17
K	.56	.42	.22	.13
L	.56	.42	.22	.17
M	.47	.32	.11	.08
N	.44	.13	.05	.03
O	.44	.51	.22	.07
P	.42	--	.13	.04
Q	.41	.16	.04	.02
R	.36	.11	.07	.03
S	.36	.31	.10	.01
T	.36	.20	.10	.05
U	.28	.18	.11	.01
V	.14	.07	.04	.01
W	.12	.11	.05	.01
Average	.53	.33	.17	.07

*Not included in averages.





URINARY EXCRETION OF MERCURY AFTER TERMINATION OF EXPOSURE

The averages of the foregoing data may also be represented in graphic form. The rate of mercury excretion in milligrams per liter of urine is plotted against the time elapsed after termination of significant exposure to mercury vapor in the two graphs shown herein. The first chart is a rectilinear graph of the data, whereas the second is a semi-logarithmic graph of the same data. It is noted that the rate of excretion approximates a straight line function of the log of the time elapsed.

These graphs may also be expressed as an equation:

$$(1)\quad R = -.51 \log T + .83$$

R = rate of mercury excretion in milligrams per liter

T = time in weeks elapsed after termination of exposure

The question at once arises whether this data might not be used to determine mercury excretion at the time of termination of exposure from the rate of excretion at any particular interval. For example, if the rate of excretion for an individual, after his exposure has been terminated for 10 weeks has been determined and found to be .30 milligrams of mercury per liter of urine, by following back parallel to the line on the chart the rate of excretion at 4 weeks is found to be approximately 0.51 milligrams of mercury per liter of urine. The same information can also be obtained from the following equation:

$$(2)\quad R = -.51 \log T + .83 \pm a$$

a = difference in rate of excretion at specified time T

The value of (a) may also be obtained independent of the graph from equation (1). In the example of .30 milligrams of mercury for the period of 10 weeks the value of (a) is -.015. Then substituting in equation (2) the excretion of mercury 4 weeks after termination of exposure would be -

$$R = -.51 \log 4 + .83 - .015$$
$$R = .51$$

In making these calculations it has been assumed that the graph for any individual under consideration parallels that of the group average for this study. An examination of the summary of individual mercury excretions reveals that this is not strictly true. It is noted that in general, the slope of the curve varies somewhat with amount of mercury initially excreted. It is evident therefore that this equation derived from the average data collected from the 23 individuals selected for this study must be used with proper reservation when applied to any other individual cases. The value of extrapolation on this graph is questionable, particularly in the regions approaching the point of termination of exposure and the time at which no more mercury will be excreted. However, it may give a rough approximation of these limits.

SUMMARY

1. An investigation of the facilities, materials, and processes of an industrial establishment engaged in the manufacture of an electrical apparatus revealed the presence of a mercury hazard.

2. Opportunity was afforded for the observation of employes of this plant during and following significant exposures to mercury in the form of vapor and amalgam dust.

3. Exposure to mercury vapor over a period of one year resulted in positive signs and symptoms of mercury poisoning in the workers examined.

4. Sore mouths, fine tremors of fingers and tongue, digestive disturbance, constipation, dysentery, skin eruptions, excessive flow of saliva, loss of weight, nausea and psychic irritability were the symptoms of mercurialism found in this study.

5. Mercury vapor samples taken with the Nordlander apparatus gave concentrations up to 85 milligrams of mercury per 10 cubic meters of air. These concentrations are not surprising since a considerable quantity of the amalgam was heated to 500°F., at which temperature the vaporization of mercury is comparatively rapid.

6. Amalgam dust samples taken with the Greenburg-Smith impinger after elimination of the mercury vapor exposure indicated that amalgam dust by reason of its greater weight settles out rapidly and concentrations rapidly decrease as the distance from the source of production increases. It is doubtful if mercury dust played a very important role in the production of symptoms of mercurialism among the employes.

7. Institution of control measures resulted in the practical disappearance of symptoms of mercurialism among employes observed and the virtual disappearance of detectable quantities of mercury fumes and dust from the general atmosphere of the factory.

8. Excretion of mercury in the urine was followed for a period of eight months after the mercury vapor exposure was terminated. The amount of mercury in the urine ranged from 1.11 to 0.01 milligrams per liter and the rate of mercury excretion was found to be a function of the log of the time elapsed after the termination of the exposure.

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